FUTURE SOLDIER Initiative

Future Soldier

"Own the Fight!"

"The goal of our Army is to continue the transformational process of building a campaign quality expeditionary Army that can support our combatant commanders in the challenges of the 21st Century across the full spectrum of conflict."

GEN George Casey

CAPABILITY DESCRIPTION

In today's world where conflict, style, and tensions seem to prevail, there is an ever greater emphasis on the uncertainty of tomorrow. Tomorrow's leaders will be those best prepared and best equipped to adopt and deal with change and the challenges it brings. By applying logic and imagination to current situations and technologies, the *Future Soldier Initiative* was developed to identify capabilities a Soldier might carry into battle. This initiative was not created to develop U.S. Army doctrine, nor is it intended to answer every question raised about future warfare. *Our intent is to start a dialogue and stir imaginations about how best to equip the Soldier of the future.*

As outlined in U.S. Army Training and Doctrine Command (TRADOC) FM 3.0 and emerging FM 3.1, "the future Soldier will be capable of full spectrum operations with role-based capabilities". The future Soldier shall be tailored with design considerations for each technology area named below with special emphasis on cognitive performance to improve Soldier effectiveness and an increase in operational tempo. There are seven major capability focus areas are:

- Human Dimension & Training
- Protection
- Lethality
- Mobility and Logistics
- Network
- Sensors
- Power & Energy

As head of the U.S. Army Research Development and Engineering Command (RDECOM) Soldier System Integration Domain, the U.S. Army Natick Soldier Research Development and Engineering Center (NSRDEC) led the development of the initial future Soldier concept with input from the other RDECs, PEO-Soldier, and the Knowledge Centers for the initial Future Soldier concept system.

The Future Soldier Initiative's purpose is to help focus and identify potential capabilities that may be required by Soldiers in the future. This work will feed the investment priorities and tradeoffs in the future (risk/payoff, $/% solution).

HUMAN DIMENSION & TRAINING

Augmented and virtual environments will be ubiquitous and will support almost every facet of warfare including communications, data visualization, system control, and training. Soldiers will be able to move seamlessly among real, augmented, and virtual environments. Virtual reality (VR) systems and serious gaming technologies will become the primary mode of delivery for personnel selection and training. Training will be embedded and available anytime, anywhere. The training would be augmented with the use of intelligent software agents and modeling and simulation tools resident on every Soldier system type, giving them analytic and decision-making capabilities that dwarf what is currently available to major command posts and rearward C4ISR centers.

Augmenting this capability would be mental and physical readiness assessments that would monitor a Soldiers status in real time using a suite of behavioral, neural, and physiological sensors that would be embedded within the all aspects of the Soldiers ensemble. The data would then be captured and used to drive command decisions regarding unit tasking, Soldier assignments, and medical/psychological intervention.

A powered exoskeleton would be available and integrated into the Soldier system. The use of the VR capability would enable Soldiers to interact with robotics, software systems, and hardware platforms via an array of "third generation" interfaces that will rely on natural language commands, gestures, and virtual display/control systems.

Consumer demand and scientific exploration will yield an explosion in cognitive and physical enhancers, including memory and cognitive enhancement (smart) drugs, neural prosthetics, and permanent physical prosthetics. These could yield dramatic enhancements in Soldier performance and provide a tremendous edge in combat, but will require the Army to grapple with very serious and difficult ethical issues. At the same time, if societal ethics change to embrace such enhancers, the Army will need to decide to use these types of systems.

Technology Concepts

Virtual and augmented realities that can be entered at any time using the visual display and auditory capabilities of headgear)

- Immersive telepresence for "spectating" remote areas of battle space (e.g., view through sensory apparatus of scout robots, ground sensors, etc.)
- Telepresence for communications – enables 3D "window" into command posts and improved communications. Also has potential to remove Warfighter from direct threat with improved human to robotic interface.
- Embedded training

ERGOGENICS

- Integrated nanotechnology based exoskeleton – improved speed, strength, and agility
- Cognitive enhancers (nutritional, nootropic or smart drugs)
- Physical, physiological, psychological enhancers (nutritional, pharmaceutical)
- Neural prosthetics (controversial now, but perhaps ubiquitous in 2030)

MENTAL & PHYSICAL STATUS MONITORING

- Behavioral
- Neural
- Internal (sensing of blood oxygenation and glucose levels, hydration)
- Linked to individual predictive model of Soldier performance as a function of state variables

PERSONAL INTELLIGENT AGENT SUBSYSTEM – SOLDIER CENTRAL

Advances in computer science will enable massive increases in processing power available to Soldier-borne computing platforms. This expanded "digital real estate" will allow every Warfighter to be paired with a personal intelligent agent (PIA), an artificial intelligence that acts as a "digital buddy". The PIA will serve a wide variety of roles, facilitating data management, serving as a central node for cognitive and physiological status monitoring, providing tactical support and expert systems recommendations, and alerting the Warfighter to crucial events in the environment.

Core capabilities:

- Monitor network data feeds to alert Soldier to mission-critical information (semantic data-bot)
- Monitor ammunition and other stores for automated calls for resupply
- Provide reminders (memory joggers)
- Anticipate information needs and facilitate data access and retrieval
- Handle routine communications based on minimal input from Soldier
- Monitor the Soldier's mental and physical state, shaping information flow, suggesting mitigations, alerting leadership
- Communicate with other PIAs to optimizing data integration and sharing across unit members
- Adapt to an individual Soldier's personality, strengths, and weaknesses
- Communicate with Soldier via a natural language interface and heads-up display (HUD)

PERSONAL MODELING AND SIMULATION TOOLS

- Facilitate decision-making by providing war-gaming capability with expert system augmentation (among other things, will be able to mimic decision-making patterns of other military strategists.
- Provide predictive tool to determine likely effects of fires – both kinetic and non-kinetic (e.g., risk of noncombatant casualties and likely impact on local support for mission)
- System provides both an operational and training capability

CULTURAL AIDS

- Automatic language translation – both productive and receptive (Soldier's speech will be automatically translated and broadcast in a realistic voice)
- Assess intent and threat level based on nonverbal behavior (system will alert Soldier to suspicious behavior)
- Cross-cultural communication/negotiation aid – a gauge that tells a Soldier how well an exchange is going and suggests paths to optimizing the exchange
- Gesture recognition and interpretation

THIRD-GENERATION HSI

- Natural language interfaces for robotics, autonomous systems, data gathering applications, etc.
- Data glove and suit for gesture-based interface with robotics, HUD
- Virtual interfaces displayed via HUD with correct location and haptic feedback
- User-defined 180 degree field of vision HUD with instantly reconfigurable modes/themes
- Soldiers will be able to assemble their own software tools and interfaces on the fly by making "mash-ups" of diverse software modules, including those that they create (assumes that computer programming becomes a common skill, perhaps realized via highly intuitive programming concepts such as "wiring together" widgets)
- Flexible, durable, light weight wrist mounted display

BIOMETRIC FACIAL RECOGNITION ALGORITHMS

- Face and feature localization even within a complex background
- Segmentation of multiple faces to isolate individuals
- Ability to collect, analyze, and act/decide on biometric data matches
- Used in check points, target recognition, intelligence capture, and biometrics

SELECTION AND TRAINING

- Optimized assignment to Military Occupational Specialty (MOS) based on VR and serious game-based aptitude testing with situated intelligence assessments (virtual live fire)
- Networked access to rich, immersive training packages – continuous learning of critical skills anytime, anywhere
- Facilitate decision-making by providing war-gaming capability with expert system augmentation (among other things, will be able to mimic decision-making patterns of other military strategists.
- Provide ability to predict likely effects of fires – both kinetic and non-kinetic (e.g., risk of noncombatant casualties and likely impact on local support for mission)

SOLDIER PROTECTION

The protection systems of the Future Soldier Initiative will be a multi-functional network of protection, signature management, physiological/medical management, and system power support. The close fitting design will enable full range of motion and tactical movement and may interface with the capabilities of an exoskeleton structure as needed.

The material of the Soldier ensemble will be multi-functional in nature to provide inherent:

- Ballistic and blast protection
- Reactive flame resistance
- Physiological, neurophysiological, and wound sensing
- Chemical/biological / radiological / toxic industrial materials protection with self-decontamination capabilities
- Wound/bleeding management
- Multi-environment microclimate conditioning

SOLDIER ENSEMBLE

The basic needs of the Soldier will be provided by the Soldier ensemble. The ensemble will feel like a second skin, instilling confidence in the system without inhibiting physical activity. Bio-inspired artificial vascular systems in materials will provide active multifunctionality for chemical/biological protection, climate control, and autonomic trauma care.

Antimicrobial properties will be engineered into the fibers of the Soldier ensemble. This will enhance health and hygiene, reducing the incidence of skin irritation and fungal growth. This promotes some degree of self-cleaning, although the basic need to launder and maintain the system is still anticipated in the future ensemble. There is also a potential to incorporate resistance to fleas, ticks, and infestation by insects.

In the future, electronic textile technology will have matured to the point of full integration in the Soldier ensemble. The power and data network will be integrated into the textile as a self-forming network across the body without bulky cables and connectors. Power generation, energy storage and signal transduction will be provided by textile-integrated batteries, piezo-electrics, fuel cells, photovoltaics, bionic energy harvesters and electrically conductive fibers. These technologies will be engineered into the Soldier ensemble to self-generate, store and harvest distributed power. The ensemble will use a Faraday cage to protect the Soldier and to receive energy from vehicle sources. Sensors throughout the system will utilize this network for physiological monitoring, wound sensing, CBRN detection, etc. This network will also provide the pathway for reacting to environmental and tactical threats, such as responsive signature management, CBRN protection, thermal loading, and wound management.

Incorporated within the ensemble will be fiber devices constructed of nano and alloy fibers designed to receive acoustical, light, electromagnetic and other optoelectronic. The integrated nanofiber system will provide combat identification with a passive and active response system, sniper detection, acoustical capture, and covert Soldier-to-Soldier communications. When a Soldier's ensemble is interrogated by the appropriate mechanism (laser, RF, EM) the ensemble will respond with a specific keyed sequence. Biometrics will be employed within the Soldier ensemble, ensuring that it is matched with a known friendly Soldier. If a Soldier expires, the system will provide a security-based zeroize function so that the enemy cannot exploit the ensemble's technology.

The future Soldier's boot will be biomechanically designed and custom fitted to improve comfort and reduce energy expenditure. The boot will also have enhanced blast protection via incorporation of nanophase materials, and provide CBRN protection equal to that of the Soldier ensemble. The system will also contain phase change materials that reduce footfall impact and increase Soldier endurance.

BALLISTIC AND BLAST PROTECTION

The armor system will be flexible and modular in nature. Today's level of fragmentation protection will be provided in a form-fitting and flexible Soldier uniform that enables natural ventilation. It will provide protection to the torso and extremities against blast effects, such as overpressure, fragmentation, traumatic amputation, and burns. A network or nanofibers and nanostructure materials is intended to make up this vital layer of protection. A conforming, flexible vest will provide protection from rifle rounds to the most critical organs. Significant additional levels of protection will be modular and attach to the built-in lower extremity exoskeleton structure. This would provide the option of full body protection for specific missions with the exoskeleton bearing the weight burden. This approach also provides significant load carriage over extended terrain or repetitive motion load handling capabilities.

Extremity protection will be greatly enhanced to include some degree of inherent protection within the Soldier uniform. Shear-thickening fluids and fabric composites would provide lightweight extremity protection. Joints would be reinforced to provide protection from blast effects and extreme movement, without limiting natural movement and function. Limited protection from cuts and fragments would be built into the Soldier uniform using a chain mail fabricated from carbon nanotubes. Additional protection to the extremities will be provided by the exoskeleton structure.

Nanotechnology is expected to significantly improve the strength and durability of textile fibers through the production of nano-composite fibers incorporating oriented, high aspect ratio, nanoscale domains. Based on current projections, a significant increase in penetrating power of projectiles is anticipated as tungsten carbide core bullets and tungsten fragmentation rounds become more widely available. The anticipated future protection systems will be composite rather than pure textile with the addition of nano-composite matrixes that react to ballistic, blast, fire, and other threats. The ballistic protection properties are projected to improve by a factor of 10 based on calculated properties for materials such as carbon nanotube-based composites.

These materials could enable the design of armor with bullet protection (against current threats) that meets the areal density goal of 3.5 lb/sq.ft. This value translates into an armor thickness of about 1.7 cm (0.67 in.) for a primarily organic material (such as a carbon nanotube reinforced polymer). A ceramic material with a true density of around 3 g/cc would result in a correspondingly thinner armor of 0.85 cm (0.33 in). A hybrid system designed with outer layers of ceramic and polymer matrix composite backing material would have a thickness of 1.7 cm value. The high strength and stiffness of these materials will allow the protective armor plates to double as mounting points. These materials would also be applicable to head protection.

REACTIVE FLAME RESISTANCE

Active Flame Resistant (FR) technologies that are responsive to active flame and thermal threats will be used in addition to maintaining the current passive flame and thermal protection maintained. Greater and reusable protection capabilities will be added to the Warfighter uniform with the development of active materials that respond to a thermal flux or a flame.

Fibers within the Soldier uniform will provide inherent flame and thermal resistance. Novel nanofibers and nano-composite materials with improved flame resistance and flame extinguishing capabilities will be engineered to provide breathability with multi-functional protection from complex threat environments. Coverage will extend to the hands and neck, meeting the protective components of the helmet with see-through facial protection.

The primary mechanism will be the development of multi-component fibers that incorporate desirable FR properties into one component with load carrying capability into the other. The thermoplastic, micro, and nano-structured nonwoven materials will create a barrier layer that stops flame without inhibiting the comfort of the wearer.

PHYSIOLOGICAL, NEUROPHYSIOLOGICAL, AND WOUND SENSING

Soldier Physiological Status Monitor (PSM) sensors and a Microclimate Delivery Network will include tiny micro-sensors embedded in the uniform, hydration system, boots, and helmet. The sensors data would be analyzed, physiological and psychological indices formulated, and a status report developed and maintained. The PSM report would contain information on energy levels, work load, hydration, stress levels, thermal state, sleep, and development of a baseline along with functions for remote triage. The triage system would be able to assess traumatic brain injury assessment, ballistic impact, and flame and blunt trauma.

A companion system using behavioral, environmental, and neurophysiological sensors would monitor Soldier cognitive status in real time to provide accurate assessments of mental

workload and cognitive readiness. This data will be used by commanders to drive tactical decisions and tasking and in adaptive C4ISR systems to optimize the flow of data and communications to the Soldier, avoiding information overload that decreases situation awareness.

These monitoring capabilities will be linked to individualized predictive models designed to enhance the validity of physical and mental performance by accomodating individual differences in cognitive and physiological dynamics.

CHEMICAL/BIOLOGICAL/RADIOLOGICAL/TOXIC INDUSTRIAL MATERIALS PROTECTION WITH SELF-DECONTAMINATION CAPABILITIES

The uniform will have an intrinsic sensing capability through the incorporation of assorted toxic agent indicators and response systems. The sensors would consist of a micro-surface acoustic wave sensor embedded in the outer layer of the garment that would provide information to the tactical processor to identify CBRN agents and toxic industrial chemicals. Upon detection of an agent, TIC (toxic industrial chemical) or TIM (toxic industrial material), the system would sense a change in pH in the outer uniform layer. The pH change would modify the resistance of the conductive nano-polymers in the uniform material that would in turn be sensed by nano-sensor sites at the intersections of the textile grid (i.e., intersection of conductive polymer fibers and/or fiber bundles). The nano-sensors signal the tactical processor to provide a warning to the Soldier that toxic substances are present. Enzymes and/or reactive nanoparticles embedded in the uniform would immediately begin to neutralize the toxic agents. Nano-composite materials such as polymer matrix/montmorillonite blends show excellent potential for use as high performance barrier materials for chemical and biological protection and have additional applications for storage or encapsulation of ration components, caseless ammunition, and for environmental hardening of microelectronic systems.

WOUND/BLEEDING MANAGEMENT

Two possible areas are available: the first area is wound treatment and the second are is the use of autonomous and self-injecting drug delivery systems. The wound treatment would incorporate means to self clean open wounds and seal the wound sites. The second area would potentially use an implantable subcutaneous auto-injector with rapid reconstitution packages to treat various types of chemical, biological, or other threats through wearable and implantable MEMS-based devices. The subcutaneous systems could also be incorporated into small externally worn devices.

MULTI-ENVIRONMENT MICROCLIMATE CONDITIONING

The Future Soldier will wear have a lightweight, low power micro-climate conditioning system (MCCS). The MCCS provides heating in cold weather and cooling in hot weather to ensure comfort, safe core body temperatures, and combat effectiveness of the Soldier over a wide range of thermal environments. The MCCS will consist of a microclimate conditioning module and the microclimate delivery network, a heat transfer layer built into the Soldier ensemble.

LETHALITY

The Future Soldier weapon system will provide unequalled lethality and versatility on the future battlefield. The weapon system will permit direct and indirect target engagements, while effecting decisively violent and suppressive target effects at extended ranges and against defilade targets. The counter defilade target engagement high explosive munitions would be effective to 1,000 meters, while the caseless kinetic energy projectiles will be effective to 600 meters. Fire control optoelectronic would be integrated into the Soldier platform, minimizing complexity on the weapon. The weapon aim point will be illuminated on the HUD and the fire control algorithms would substantially increase the number of observable targets in military operations in urban terrain (MOUT), jungle, desert, and rural environments by electronically tagging targets in the Headgear system's display. Wireless connectivity to the digital battlefield extends the lethality dimension by creating a "virtual trigger" capability for each Soldier. All dismounted Soldiers will have a "forward observer" capability and will be able to call-for-fire from a suite of air, ground, and water lethality platforms.

The Weapon Subsystem operation is as follows. The target is acquired through normal line-of-sight or through a weapon or headgear mounted sensor. The weapon aim point is illuminated in the HUD and placed on or near the target. A voice actuated or electronic trigger is activated which launches the projectile out of the lightweight weapon platform. The munitions will violently explode at the target affecting a 5+m^2 lethal area. For close-in battle, the rifle will also fire caseless kinetic energy munitions. These munitions provide the maximum lethality for a fraction of the weight and size of current brass cased ammunition. The rifle itself provides a highly ergonomic, low recoil platform for aiming and firing the ammunition. Key enabling technologies for the lethality include:

Weapon/Munitions Pod
- Low Recoil mechanisms
- Nano-composite materials
- Electronic ignition
- Caseless Kinetic Energy Rifle

Fire Control
- Micro-sensors/hyper spectral electro-optics/sensor fusion
- Polymer/adaptive and plastic zooming optics
- Optical Augmentation with dazzle/stun features
- Target state estimation and prediction with predicted target de-confliction
- Target geo-location and hand-off
- Laser radar for closed loop target and munitions tracking and munitions guidance
- Wireless link to Soldier
- Effect based weapon – target pairing algorithm
- Target classification
- Collaborative engagement
- Non-magnetic digital compass

Munitions
- Caseless munitions

- Air bursting and scalable munitions of incremental levels of lethality (ranging from non-lethal to lethal)
- Family of guided small caliber munitions

MOBILITY & LOGISTICS

The future Soldier will be enabled both in areas of advanced strength / extreme endurance as well as complete protection and unique lethality created by a modular and tailored exoskeleton system. The advanced system will be configured as the mission dictates allowing the Soldier quickly change/modify critical components of the Exoskeleton to better accomplish a variety of missions.

Specific missions might include:

- Individual Soldier sensor platform
- Individual advanced weapons platform
- Squad level weapons platform
- Chemical protection
- Ballistics and pulsed energy protection
- Medical aid and recovery platform
- Logistical platform
- Construction and search and rescue
- Barrier breaching platform
- Ammunition handler
- Logistics support

EXOSKELETON: LOWER BODY UNIT (LBU)

A Soldier may be outfitted with a form fitted lower body exoskeleton which will be the foundation for all other applications/modifications to the platform. The lower body unit (LBU) will be unique to that Soldier, providing components that are molded specifically to meet the needs of that Soldier. The Lower Body unit will stay with that Soldier as the that Soldier transfers from unit to unit throughout their career.

The LBU will provide strength augmentation to the legs and act as a load carriage platform if necessary. The LBU will have its own power source and can be used to power external radios, recharge electronics, power weapons/sensors. The LBU will be capable of being up-armored as well as uncased for chemical / pulsed energy weapon protection. Advanced lightweight polymers and electronics that are field repairable with simple tools embedded within the exoskeleton limbs within the LBU. Although lightweight, the LBU will feel weightless to the Soldier. The LBU will be designed with an Intuitive Learning System that will over time, learn the unique gate and muscle actions of that Soldier. So in times of injury or mobility restrictive wounds, the LBU can assist by “moving” for the Soldier using the gate and muscle actions that the LBU has learned.

As the missions, environments, and threats change, then the enabling exoskeleton would be modified. The LBU will be designed to work independently or in concert with one of several mission enhancement chassis (MAC) options that will be available.

EXOSKELETON: MISSION ENHANCEMENT CHASSIS (MEC)

Each MEC will be self-powered to provide additional power and redundancy. A Soldier upon receiving his mission specific details will work with the Squad to allocate capabilities and distribute options. Each MEC will be designed to accomplish a base set of capabilities:

- Enhanced strength and muscle endurance
- Impact and blunt trauma protection
- Self Power options
- Recharge capability
- Unique load carriage options
- Ballistic and Up-armor protection
- Interlocking with LBU creating a full body exoskeleton
- Advanced Headgear Integration

Each MEC option will be unique to the specific MEC platform/model. For instance, the Individual Soldier Sensor Platform will be integrated with the most advanced sensor Network providing the best capability to detect or identify the enemy threats while continuing to perform all base capabilities.

ADVANCE INDIVIDUAL OR SQUAD LEVEL WEAPONS

The platforms will be linked and networked to each squad member. Understanding and utilizing squad level lethality at all times. Each Weapons MAC will have basic individual weapons but also have the ability to attach squad level assets to the chassis. The weapons have the option of using the MAC exoskeleton power or being self-powered along with integrating into the sighting and heads-ups positioning of the Headgear system. The Weapons MAC will have unique ammunition storage relevant to that Weapon system.

BALLISTIC & PULSED ENERGY PROTECTION

All MAC's will have the option providing advanced ballistic and pulsed energy weapons protection to the operator. Both the LBU and MAC will be able to accept modular up-armor components as well as energy absorbing and deflecting shields. The components and shields will act as part of the integrated full exoskeleton system.

CONSTRUCTION & URBAN SEARCH AND RESCUE (C&USR)

The C&USR MEC will feature unique strength and material handling options unavailable in the other MEC's. The C&USR MAC will sacrifice some agility to handle extreme lifting and very heavy overhead lifts. This MAC will also be configured with unique end effectors allowing the exoskeleton to cut through and dismantle vehicles for emergency search and rescue situations; including the ability to torch cut, weld, Jaws-of-life, bolt cutters, and various hand held tools.

All other modular MEC's options will be similar in concept offering unique mission driven capabilities while being fully integrated.

All exoskeleton components will be completely sealed to provide system protection, environmental protection, and protect the Soldier. Sealing the components will allow the exoskeleton to be submerged without interrupting function.

LOGISTICAL SUPPORT

The future Soldier logistical support system will incorporate means to identify, track, and deliver the assets required in a timely and effective manner. The support package will be linked to the command and control system that should minimize data entry and increase awareness of logistical issues early and effectively.

The logistical system will contain automated devices, informing the Soldier's communications system the status and state of equipment and materiel. The system will incorporate RF sensors or next generation devices. The data will be fused and transmitted during periods of reduced communications traffic as warranted by the tactical and logistical leadership.

SOLDIER NETWORK

The principal needs of the Army for tactical command, control, and communications (C3) applications fall into two categories. First, to enhance the lethality of the Future Soldier, advanced information technologies are needed to ensure reliable, wideband, networked communications over an area commensurate to the evolving battlefield environments. Second, for the Future Soldier Initiative to maintain information dominance, the situational awareness data set must reflect higher-level tactical internet and global command and control system network intelligence.

The next generation communication systems would deploy the technology of cognitive reasoning. Cognitive Networks would allow the network to continuously learn from external situational data and internal performance data to predict and adapt to changes in the needs of the user and the dynamics of the battlefield environment. The cognitive network would provide optimal communications performance to the Soldier. Cognitive Networks would include the ability to adapt to constrained spectrum resources and scenario driven application traffic demands and to provide mission-shaped information to the individual Warfighter. The network planning burden would be dramatically reduced and allow the Warfighter and C3 elements to focus on the mission. The Cognitive Network would enable spectrum supportability through control algorithms and adaptive networking capabilities.

Key enabling technologies for the Network include:

- Software Defined Radio Systems that allow for growth and reuse with their ability to be reprogrammed
  - ✓ Multi-band, multi-mode, and open system radio architecture based on joint standards (e.g., the 2030 follow-on to the Joint Tactical Radio System)
  - ✓ Utilization of multiple waveforms using EM, RF, IR, and optical
- All terrain communications
- Adaptive media access and link layer transmission protocols
- Quality of Service Mechanisms
- Lifeline communications (highly reliable, low data rate for extended range)

- Improved radio power efficiency to minimize power consumption
- Scalability to large numbers of nodes
- Low probability of intercept/detect communications signal
- Improved jamming resistance against multiple threats
- Advanced processing applications to use Cooperative Diversity Antennas
- Position Location Information in GPS denied environments
- Multiple levels of security for dismounted applications
- Automatic and continuous proactive nomination of location patterns for Soldier-placed sensors
- Remote unattended sensor clusters networked to the Future Soldier system
- Planning aids and automatic execution monitoring optimized for small computing platforms using limited power
- Voice recognition and speech synthesis (hands-free control of Soldier assets)
- Leveraging of commercial capabilities and standards to reduce cost and provide solutions to the Soldier faster

FUTURE SOLDIER ANTENNA SYSTEM

Antenna apertures for the Future Soldier are envisioned as conformal sub-systems of the Soldier platform, visually inconspicuous, lightweight and fully distributed around the Soldier's exoskeleton to support a variety of multifunctional operations. Enabling technologies include nano-antenna array structures, RF nano switches, resonators and filters; photonic- based antenna feed systems; reconfigurable morphing antenna structures (antenna elements that can change their shape and radiation characteristics using electrically excited polymers); and holographic antenna structures which enable the electromagnetic wave to bend around obstacles on the Soldier system and provide better pattern coverage.

The core capabilities provided by the antenna technologies include:

- Adaptive beam steering, nulling, and beam width control to adapt to the spatial and spectral environments and increase the performance of the Soldier Cognitive Radio and network
- Communications (Omni-directional and directional) to support the full suite of deployed waveforms
- Directed energy applications for crowd dispersion
- Threat jamming
- Direction finding
- Power collection through nano-antenna arrays to provide power to active antenna elements/modules and augment fuel cells to extend mission duration

SOLDIER SENSORS

HEADGEAR SYSTEM

The headgear system of the Future Soldier incorporates sophisticated "all directions" display technology for high fidelity vision under all battlefield conditions. The headgear system would incorporate a neuro-cap electronic sensor suite to monitor brain activity, giving a complete picture of brain activity during task performance that would feed the human performance and training capability. Also incorporated into the headgear will be high performance transparent materials for Soldier and sensor protection, multi-band, multi-mode radio frequency communications for receipt and transmission of critical situational awareness data and command and control information, three dimensional audio queuing, and complete protection from ballistic and CBRN threats.

The headgear system will incorporate sophisticated display the technology via development of nanotechnology materials. For example, highly ordered carbon nanotube arrays will be used to create a Field Emission Visor Display for the Future Soldier. This type of display will have very high resolution due to the large number of effective pixels created by the array. Onboard processing will "warp" (i.e., intentionally distort the image or arrange the pixels) the image to match the curvature of the visor. The viewing angle will be extremely wide (~180 degrees), and energy consumption will be very low, thanks to the large number of emitters and the resulting large emission current (high luminance efficiency) at low power input. The headgear system will also have 360-degree situational and environmental awareness through the exploitation of onboard sensors (a single, 360 degree, hyper-spectral helmet-mounted sensor that provides images that are visually registered with the visor display/Soldier viewing angle) and organizational sensor fusion (remote sensors, UAVs, satellite, imagery link to command centers).

High performance transparent materials will be utilized in the visor display for both human eye and synthetic sensor protection from laser threats. The visor display system would employ a flexible display embedded into the helmet's visor to provide real-time situational awareness and well as a night vision and thermal device viewing. In addition, novel transparent ceramics such as aluminum oxynitride (ALON) spinels or transparent composites with nanophase reinforcement are projected to provide up to 5 times the performance of current transparent materials. Composite transparencies will be possible with properly dispersed nanophase reinforcement since the reinforcing particle size is too small to scatter light. Carbon nanotube arrays or other forms of nanoscale-dispersed carbon will limit the transmission of directed energy beams. When nanoscale dispersed carbon is "hit" with a directed energy beam, the material will transform into a plasma state, thereby absorbing the energy.

A microelectronics/optics suite integrated into the Headgear system will provide unaided visual, thermal, light amplified, acoustic, CBRN detection with laser radar (LADAR) and radar sensor fusion. Multi-band, multi-mode radio frequency (RF/non-RF) communications will permit remote operation of micro machines, unattended micro sensors, and/or miniature land robotic devices; communication with organizational assets such as micro UAV; remote detection of CB agents; and communication with non-organizational assets such as large UAVs and space-based

satellites. These latter assets will employ a variety of imaging/non-imaging and moving target radar sensors, which will provide situation relevant data directly to the Future Soldier. System-on-chip (SOC) embedded processing integrated into the headgear system will meld these data into a fused, coherent, tactical situational picture (perhaps displayed as a "situational avatar" on the Soldier's tactical display).

Three-dimensional audio queuing will be utilized to maximize the inherent ability of the human mind to spatially differentiate audio information (an auxiliary vibration device could be utilized to draw attention during silent operational modes).

Respiratory and CBRN protection will be integrated into the Headgear system. Headgear materials and coatings will provide dual use functionality by combining chemical/biological survivability with ballistic protection. This will be achieved using highly dispersed nanoscale inorganic fillers. Air management for respiration, defog, and creating an air curtain barrier will be controlled by circulating mesoscale machines (activated by the helmet mounted chemical sensors). Highly reactive, high surface area nanofiber and passive filtration systems will be embedded in the headgear liners for emergency protection.

Biometric facial recognition capability could be incorporated into the headgear system. The end user will be able to use the Headgear to view unknown individuals within the field of view reticle markings. This will be achieved through development of new software biometric algorithms and disparity (range) maps enabling the individual (or region of interest) to be selected and identified in real time using a 3D scene segmentation technique and a 2D database comparator. The headgear system will allow measurements of the physical and behavior characteristics of an individual and to collect, match, store, share, and communicate the biometric data information to other tactical units.

As improvements in the leveraging of integrating optic devices with advanced biometric face localization software algorithms are made, the Headgear system will provide several improvements. These include the ability to improve face localization in a complex scene or background, provide improved imaging spatial resolution, segmentation of multiple faces to isolate an individual of interest and reduce range resolution errors.

The headgear system will be able to provide face detection and store or compare those images against an established repository of biometric data and make face positive detection and identification of targets.

The headgear display permits situational awareness from "all directions" and provides protection from blast, ballistic, laser, and other threats. The Soldier will be given 360-degree environmental and situational awareness with a 180-degree Field of View (FOV) emissive display. The display will be capable of the following:

- Optical Zoom Lenses
- Selective Angle to permit registration of remote sensor view
- Auto focus
- Agile Laser Eye Protection
- Optical Distortion and Perspective Correction (i.e., warping)

The sensor emitters on the headgear will assist in navigation, determination of target locations, target designation, combat ID, amplification devices, and movement detection sensors. Sensor fusion of laser rangefinder, chemical/biological sensors, and radar sensors provides a 360-

degree detection of CBRN aerosol and vapor clouds at a distance up to 2 km. The sensors would also feed a weather decision system that would enable weather forecasting with feeds to lethality, medical, and environmental systems.

The sensors on the helmet could consist of the following:

- Laser Rangefinder/Designator, LADAR
- Secondary Infrared Illumination
- Network Assist for GPS (RF Ranging Signal) that helps Soldiers determine the origin of the GPS signal, the time sequence, strength of the signal
- Radar (to detect movement)
- Hyper-spectral image processing and display
- Laser and Environmentally Hardened Sensors will provides sensor selection through nanometer range via digital signal processing
  - ✓ Laser (detection of unfriendly queries and reception of friendly Combat ID)
  - ✓ Thermal
  - ✓ Acoustic
  - ✓ Light Amplification (Image Intensification)
  - ✓ Unaided Vision

In addition, the sensors on the helmet would incorporate geo spatial registration and weapon targeting features that assist in navigation, sniper detection, biometric facial recognition, and target detection:

- Head Tracker
- Eye Tracker
- Geo-location Devices (inertial, MEMS gyros, and non-magnetic digital compass) Biometric facial recognition algorithms will allow:
- Face and feature localization even within a complex background
  - ✓ Segmentation of multiple faces to isolate individuals
  - ✓ Ability to collect, analyze, then decide/act on biometric data matches

Due to the dramatic reduction in the size of electronics, the headgear would contain a tactical radio transceiver and processors with high fidelity audio. The communications and processing system would have a high data rate linkage to allow teleoperation of sensors and unmanned devices along with the ability to perform cognitive systems described earlier. The processing system would incorporate a quantum dot terabyte storage system to hold the tactical maps, databases, and language translation systems.

The audio system on the headgear would incorporate a 3D audio spatial orientation delivered to the Soldier via bone conduction, in-ear, and external speakers. The bone conduction audio technology offers ears-free, mouth/face-free, and hands-free in both stealthy and high noise environments (up to 110-115 dB within tracked vehicles). The in-ear system may perform as hearing protection and audio delivery method.

Major advances in processing, neural networking, cognitive radios will dramatically increase the ability of the Soldier to see first, understand first, act decisively, and survive in high-threat environments.

WARFIGHTER ROBOTICS

As a result of the execution of the Global War on Terror (GWOT) the benefits of unmanned systems in the battle space have been clearly realized. Rapid advancements in the miniaturization of technologies that support unmanned systems will enable the development of ever smaller and more capable unmanned platforms allowing them to carry out an increasing number of mission sets in increasingly complex terrains. In addition to advancements in unmanned platform technology will come never seen before control logic improvements incorporating cooperative behavior protocols or Swarming. These technology advancements will allow micro and small unmanned platforms of the future to operate in missions across the full spectrum of conflict including Direct Action (DA), Intelligence, Surveillance, and Reconnaissance (ISR), Communications Relay, Electronic Warfare (EW), CBRN detection, Battle Damage Assessment (BDA), and the precision strike of high value targets.

As the asymmetric battlefield continues to evolve and the fact that United States will continue to face non-traditional combatant forces that operate and take refuge in complex terrains such as the mountains of Afghanistan or the cities of Iraq, so will the unmanned platforms of the American Warfighter have to evolve. No longer should it be expected that the Soldier will carry dedicated unmanned systems to operate in the air, on the land, in the water, or as a stationary unattended ground sensor. The future Soldier will be equipped with a single unmanned platform capable of operating in multiple environments of the complex battle space-conducting missions through the mazes of city buildings, streets, vehicles, tunnels, and waterways along with operations in mountain valleys, ridges, caves, and rivers. The single multi-environment unmanned platform will greatly expand the Soldier's battlefield capability while reducing his load and logistics burden.

The critical capability featured in the future Soldier's small/micro unmanned platform for will be autonomy. Soldier's involved in combat operations within complex terrain cannot be expected to partition a large percentage of their attention to direct control and management of unmanned platforms. Ongoing research to minimize the required cognitive and physical workload associated with the operation of unmanned platforms is essential to achieving the desired operational capabilities for the future Soldier. Advances in communications, control algorithms, and sensing will enable the development of an autonomous small / micro Warfighter unmanned platform capable of navigating complex terrain through Soldier tasking and not discrete control.

The planned low cost, reliable, flexible, and lethal small-unmanned platform of 2030 will play a critical role for the Soldier of tomorrow.

SOLDIER POWER & ENERGY

The main power source would be a hybrid device located on the body and consisting of a multi-fueled generator combined with a small rechargeable battery. The multi-fueled generator would convert any liquid fuel available in the field (methanol, butanol, jet fuel, diesel, and non-fossil fuel products) directly into electricity via electrochemical means, quietly and efficiently. The rechargeable battery would be a high efficiency nano-structured solid-state composite with lithium nickel cobalt manganese cathode and silicon carbon-black anode. The electronics would also be powered by lightweight, rechargeable, polymeric nano-fiber battery patches (energy densities of ~200 whr/kg) embedded in critical components. The small, flat battery patch would weigh less than 1 ounce. When fully charged, these small-distributed power sources would provide enough energy to power the Soldier for up to 3 hours. The generator and the rechargeable battery would be extremely energy and power dense and provide power the the Soldier for up to 4 days. The Soldier ensemble will also contain a nano fiber system to capture energy transmitted to the ensemble. The wireless energy transfer system would enable Soldier to recharge without plugging into a device. The energy would be transmitted from the vehicle or other secondary system.

The electronics batteries would recharged from the central power source by high-efficiency wireless power transfer via strongly coupled magnetic resonances. A hybrid device consisting of a piezoelectric generator (in close contact with chest) and a thin-film rechargeable battery essentially eliminating recharge requirement would power the physiological status monitoring devices.

A cogeneration device that simultaneously produces electric power for heat or cooling using thermoelectric principles would provide the future Soldier with climate conditioning (heating and cooling). A hybrid device consisting of a multi-fueled external combustion engine or fuel cell with a high power rechargeable battery would power the exoskeleton.

All power systems would be designed to maximize power use, recapture, scavenging, and harvesting to limit supply chain needs. The power system would be intelligent with a power management and cross communication between power and network components (power type, state of charge, demand).